Modeling and Measurement of Acoustic Coherence Degradation due to Volume Randomness

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LONG-TERM GOALS

Our long term goal is to understand how shallow water internal waves affect acoustic propagation. Another goal is to develop an understanding of the dynamics of shallow water internal waves and to relate this understanding to acoustics. Similarities and differences with open ocean internal waves are of interest.

OBJECTIVES

At least two internal wave processes are present in shallow water: a background continuum of internal waves analogous to the deep water field, and “deterministic” internal wave trains known as solibores that can dominate the displacement field over significant time periods. These “deterministic” wave trains are present in many shallow water areas of the world oceans. This work is directed toward developing models for use in explaining how these two processes, in particular their horizontal properties, can impact the coherence of acoustic signals measured along horizontal receiving arrays.

APPROACH

An acoustic propagation experiment was conducted by APL in the mid-Atlantic Bight at the same time as internal waves were monitored by a team from Oregon State University. These measurements were components of the Synthetic Aperture Sonar Primer of the 1996 Coastal Mixing and Optics Experiment. Our approach consists of developing a statistical internal wave model analogous to that of the deep water internal wave model of Garrett and Munk. Our model is used to describe an internal wave continuum that we conjecture exists as a background to the episodic solibore events associated with the baroclinic tide. The solibore events are modeled in a deterministic manner as a mode 1 process displacing isopycnals. This two-component model is used in acoustic fluctuation theory to predict phase fluctuations in acoustics signals propagated over two volume refracted paths: a lower path propagating near the bottom and an upper path that samples the shallower and more energetic, near surface field.

WORK COMPLETED

Mode shapes and parameters for the background internal wave model have been evaluated using CTD profiles and ADCP current spectra obtained by the OSU-teams. Even for this background continuum, it is apparent that there is a solibore influence at high frequencies and an extended spectral model with a peak at 2-3 cph has been used. The background model is used to estimate the acoustic phase variance along the horizontal array for a quiescent period between solibore “events”. For an identified solibore event, a simple mode 1 displacement model with associated amplitude of this mode as a function of time was obtained using temperature records observed at the OSU mooring. Estimating the speed of the solibore as it propagates past two horizontally separated moorings provides a spatially propagating solibore model that can be used to estimate displacements along the SAS acoustic paths.

RESULTS

The SAS continuum model compares well with available spectra. The modal-bandwidth is low as is known from shallow water observations. The bandwidth parameter, j*, was determined to be zero from the vertical variation of current variance. The energy parameter is about half that found in the deep ocean. When used in predicting phase variance along the SAS array for the lower path, the overall phase variance (Φ^2) could not be determined because of uncertainty in the background sound speed gradient. However, by taking careful account of the SAS receiving array geometry, the normalized phase variance as a function of receiver position compares well with the observations (Figure 1). We discovered that it was crucial to include the fact that the receiver arm had a small 2° tilt, which we had expected to be entirely negligible.

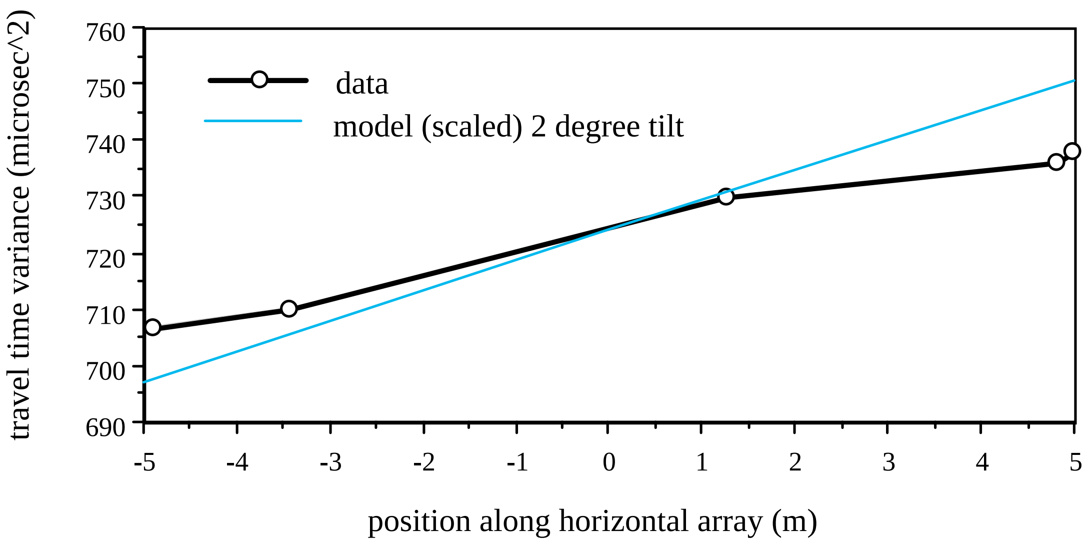

Figure 1.
Model prediction compared with the observed travel time variance as a function of horizontal position along the SAS Primer receiving array. Because of the sensitivity to the background sound speed gradient, the model has been scaled to match the measured variance near the center of the array. The tilt of the receiving arm determines the slope of the model curve.

In Figure 2, the deterministic prediction for the effect on the acoustic travel time due to the propagation of the solibore across the range is compared with the measurements. The onset of the disturbance and period of the first few peaks in displacement compare well with the measured travel times along the upper path. The disturbance, particularly on the lower path, is less than that observed and this observation along with poorer agreement as time goes on implies our simple model is deficient. For example, it has been suggested that two crossing solibores were present.

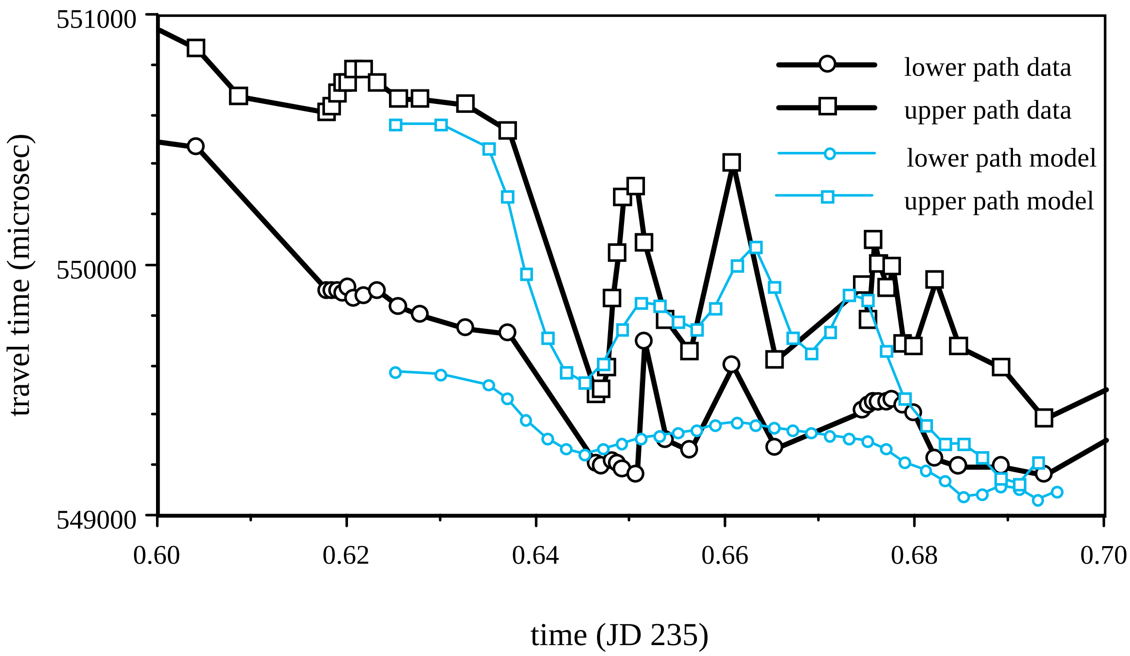

Figure 2.
Modeled and measured travel times along the SAS lower and upper paths during the initial passage of a solibore.

IMPACT/APPLICATIONS

The data set collected in the Synthetic Aperture Sonar Primer is a valuable resource for understanding acoustic propagation through internal waves, especially in regard to issues of the inapplicability of standard approximations to the upper path propagation.

TRANSITIONS

The fact that the internal waves cause significant distortions of the acoustic wavefronts plays a major role in planning for the development of synthetic aperture sonar systems.

RELATED PROJECTS

The SAS Primer was a component of the Coastal Mixing and Optics Experimental Program. The Dynamics of Shallow-water Internal Waves project aims to understand the internal wave field that affects the acoustics. The New England Shelfbreak Front Primer and the SWARM experiment investigated the effects of shallow-water internal waves on lower-frequency acoustic propagation.